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ISOSTATIC MOLDING OF COMPLEX-SHAPED CERAMIC ARTICLES

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Methods for molding complex-shaped articles using hydrostatic molding are discussed. The development of adjustable stopping devices and hydrovibrators provides for good filling of the ribs and flanges of articles by molding powder. The possibility of producing such articles by quasi-isostatic (volumetric) compression is demonstrated.

Hydrostatic molding of ceramics has been the most thoroughly studied for insulator production [1]. Technologies have been developed for dry hydrostatic molding of smooth bushing insulators of height 320, 430, and 600 mm, stop couplings of height 720 mm, thin-walled cones for space rockets up to 500 mm height with a wall thickness of 5 mm, arc-suppressing chamber insulators made from aluminum oxide materials, corundum pipes of diameter 11 mm and length 125 mm, etc. Some of the products developed are in serial production.

Researchers on hydrostatic molding of electroceramic articles pay special attention to developing technologies for making articles of complex shapes, since the majority of high-voltage porcelain insulators have a ribbed configuration. We have developed a technology for producing ribbed insulators, such as tie-rods, pot condensers, and ribbed (“winged”) insulators. The main difficulty in molding these articles is to ensure complete filling of flange, rib, and wing parts with molding powder. Whereas in molding simple-shape articles the mold-filling coefficient is equal to 1, for rubbed shapes with a rib overhang of 50 mm and an angle of 25° this coefficient is equal to 0.73, and for shapes with the same rib overhang and angle of 15° it is 0.70. This shows that standard powder charging (without vibration) leaves a part of the rib unfilled with molding powder, regardless of its moisture.

The significant factors in hydrostatic molding of high-voltage insulators are not only the properties of molding powder and the conditions of its vibration compaction ensuring adequate filling of the mold, but the conditions of vacuum treatment of powder as well. Hydrostatic molding proceeds in tightly sealed elastic shells from which air cannot be removed; therefore, a molded article gets destroyed at the moment the pressure is removed and it is impossible to extract the molded perform, especially of a substantial size, from the hydrostat. The air compression coefficient in hydrostatic molding is 2 – 3 times higher than in normal static molding [2]. For porcelain molding powder of moisture 10% in the absence of vacuum treatment the air pressure in the preform pores at the end of molding (15 MPa) reaches 1.1 MPa. With further increase in the moisture of powder the air pressure in pores sharply increases and is equal to 5.4 MPa for powders of moisture 14%. This high air pressure is responsible for stratification and crack formation in the product.

An insufficient vacuum value (600 and 650 mm of mercury column) or a substantial extension of exposure in this vacuum do not fully prevent the phenomenon of stratification in molded preforms. Only raising the vacuum to 740 – 750 mm of mercury makes it possible to completely avoid the formation of stratification cracks within a wide pressure range (up to 100 MPa) and ensure good quality of molded articles.

To develop a molding technology for tie-rod insulators and pot condensers, we have developed a hydrostatic molding plant. Molding was performed using porcelain and steatite molding powders and calcium titanate under a molding pressure of 20 MPa. Vibration was performed by laboratory vibrators during the charging of molding powder into the mold and for 10 – 30 sec after the total volume of the powder is loaded into the rubber shell. The vibrators provided for good compaction of powder in the entire volume of the article molded. The vacuum treatment of the powder was performed after the end of vibration.

A technology for the hydrostatic molding of a bushing insulator was developed, which is a most complicated article

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due to its large overhang of the rib (Fig. 1). The ratio of the rib diameter to its base diameter is 1.85.

In developing this technology, we had to design adjustable stopping devices and a rubber shell. Several variants have been designed. After experimental testing the optimum designs were selected, which ensure the removal of a preform from the hydrostat without breaking it.

The main difficulty in this technology was to ensure the complete filling of the ribs with molding powder. The vibrators that had been used for other articles did not ensure the required filling of the molds. Implementing vibration inside a hydrostat using the standard vibration methods applied in hydrostatic molding was impossible due to the large weight of the hydrostat.

It was also technically impossible to implement vibration outside the hydrostat with subsequent immersion of the preform into the hydrostat chamber, due to the complex configuration of the article molded. We could solve this problem only after designing a hydrovibrator that ensured the vibration of the molding liquid in the molding chamber. These vibrations were transmitted from the center to the periphery and back. The developed vibration regimes (amplitude, vibration frequency, and vibration duration) made it possible to ensure adequate filling of the insulator ribs by the molding powder.

Articles were molded from porcelain powder of moisture 10 – 12% at a molding pressure of 25 MPa.

The implementation of the developed technical solutions made it possible to produce complex-shaped articles with stable sizes and high quality.

However, the method of hydrostatic molding has some substantial drawbacks, which were detected by us in the course of long-term research and implementation of this technology in serial production of insulators. In other words, hydrostatic molding is a complicated process requiring substantial capital and energy consumption, large production spaces required for the machinery, and costly hydrostats that can be manufactured only by specialized industrial enterprises. The process has low efficiency, and hydrostats are complicated machines consuming a lot of metal and, therefore, requiring substantial time and material costs. Furthermore, the hydrostatic molding method provides for the radial biaxial compression of material, which leads to the insufficient compression of the ends of the article in molding, which in some cases requires additional machining (cutting off edges) of the molded product and, consequently, involves additional equipment and labor.

All this stimulated research on molding complex-shaped articles by quasi-isostatic molding, which is the simplest, the most perfect, and the most cost-effective of all known methods for molding articles from powder materials.

The method of quasi-isostatic molding was developed by us as an upgrade of the hydrostatic molding method. It combines the advantages of hydrostatic (biaxial) and static (uniaxial) molding, is the only industrial method ensuring volumetric (triaxial) compression of material in molding, and has a high efficiency.

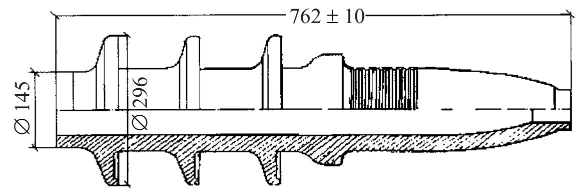

Fig. 1. Ribbed bushing insulator.

This method was used to obtain a wide range of simple-shape articles from plastic and nonplastic materials, This method has been implemented at nine ceramic factories and in experimental divisions of five companies [3 – 5].

Quasi-isostatic molding was used to make ribbed insulators.

A technology for producing a pot condenser with a wing on the outer surface has been developed as well. Two molds have been designed for this condenser: a mold transmitting the vertical pressure of the press, i.e., parallel to the axis of the article molded, and a mold with a horizontal pressure application, i.e., perpendicular to the axis of the article. Both variants of the molds use the principle of compressing molding powder from the periphery to the central axis. The molds are equipped with IV-29 pneumatic vibrators ensuring uniform filling of the entire volume of the mold by the molding powder.

Initially electromechanical vibrators IV-25 were used in quasi-isostatic molding, which ensured good compressibility of the powder and were reliable in service. However, they have a number of drawbacks. First, electromechanical vibrators do not allow for controlling vibration frequency and amplitude, which is needed when the granulometric composition of the molding powder or the content of the technological binder varies or when the overall dimensions of molded articles are modified. Vibration conditions can be modified only using several vibrators with different technical parameters, which causes complications in the production process.

Pneumatic vibrators differ from electromechanical ones: They provide for the control of vibration conditions over a wide range, have relatively small size and weight, and are simple and convenient in service. They have proven reliable in operation and are easy to fix to the molds. Such vibrators can be used in different molds for quasi-isostatic molding.

The scheme of the mold for quasi-isostatic molding of a pot condenser with a horizontal pressure transfer through the punches is shown in Fig. 2.

The technology for producing two types of pot condensers of height 120 and 170 mm, tie-rod insulator and ribbed insulator rings of diameter 150 and 130 mm and height from 70 to 90 mm with 7 – 8 ribs and a rib overhang of 5 mm has been implemented in serial production.

Quasi-isostatic molding ensures high quality of molded articles due to the volumetric pressure applied to the material

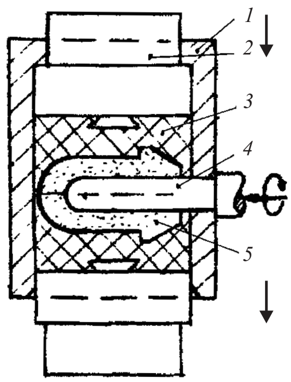

Fig. 2. Mold for quasi-isostatic molding of pot condenser: *1*) matrix; *2*) punch; *3*) detachable press buffer; *4*) core with built-in vibrator; *5*) article molded.

molded, uniform equal density in the total volume of the molded product, and, consequently, a uniform distribution of inner stresses, which prevents the deformation of product in firing. Quasi-isostatic molding is a waste-free technology, is cost effective and versatile, and makes it possible to mold articles of simple or more complicated shapes. The height of molded articles is currently limited by the open height of the press used: It is possible to mold articles of height that is 3.5 – 4 times less than the open press height.

The technology of isostatic molding of high-voltage insulators can be used to mold other ceramic products of a complex configuration.

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